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Five (5) Reasons

why the

Most Interesting,

Most Exciting,

and

Most Important

OBJECTS TO OBSERVE

(Interferometrically or Otherwise)

are

Binary Stars

FIVE REASONS ...

1. Binaries as Scales
2. Binaries as Yardsticks
3. Binaries and Stellar Evolution
4. Binaries in Other Guises
5. Binaries as "Vermin"

Current status of binary star observations

Reason 1: Binaries as Scales

- Mass is **THE** fundamental quantity — determines luminosity, size, lifetime, heavy element generation, ultimate fate.
- Need binaries to get masses!

But why is interferometry important in binary star work? A two-part answer:

Part 1: No single observing technique yields all necessary information

Example: astrometric or "visual" orbit $\rightarrow$ P, a'', T, e, plus orientation angles i, Ω, ω

But Kepler's Third requires linear separation a

Spectroscopic orbit $\rightarrow$ P and $a\,sin\,i$ ($a_1\,sin\,i$ and $a_2\,sin\,i$ if SB2)

Therefore need complementary techniques.

Distance + astrometric orbit $\rightarrow a \rightarrow$ mass sum

Particularly useful: spectroscopic + astrometric (yields individual masses if SB2)

Part 2: Different observing techniques results in different separation or period regimes

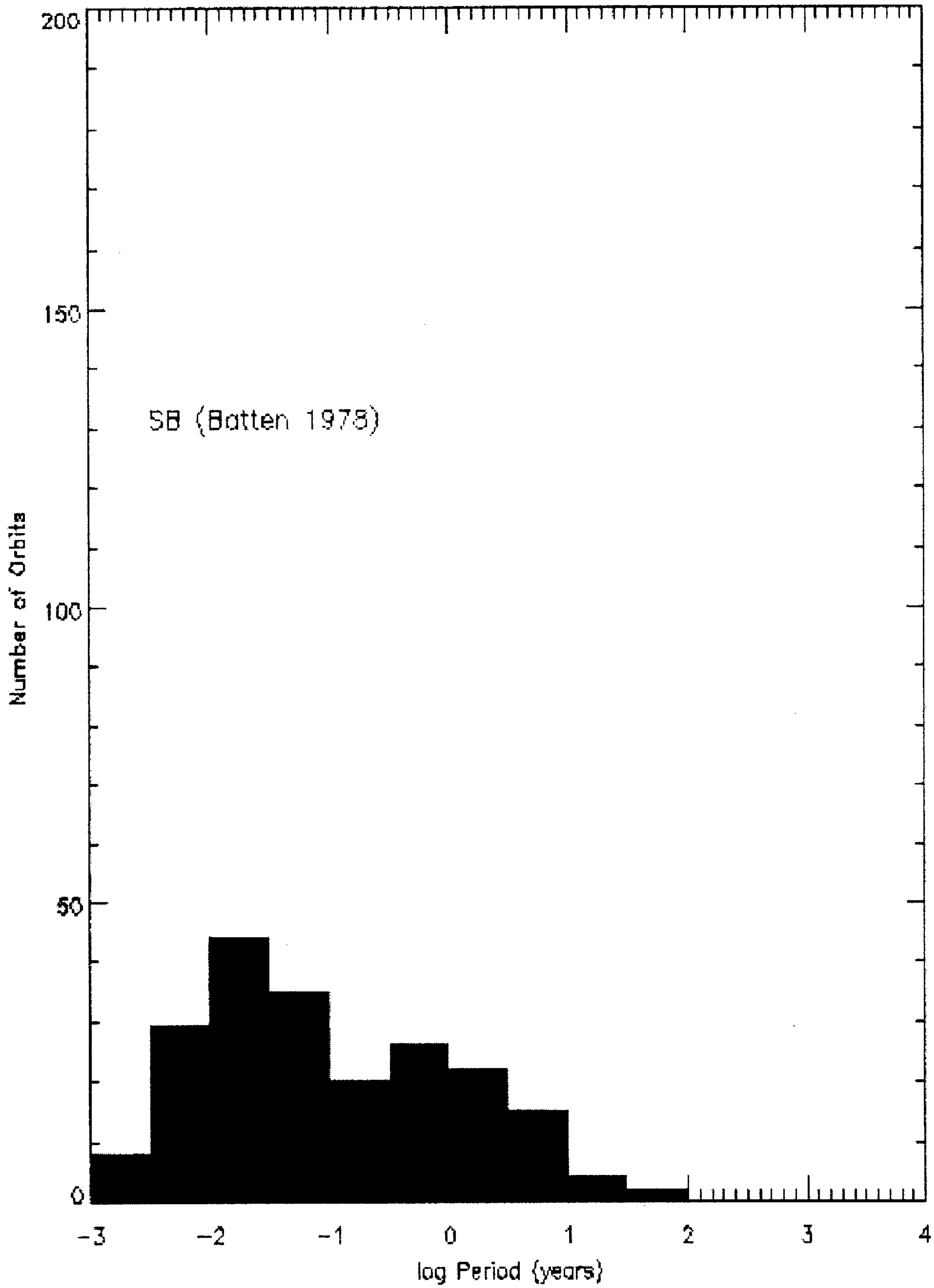
- Astrometry: wide, long-period systems
- Spectroscopy: close, short-period systems

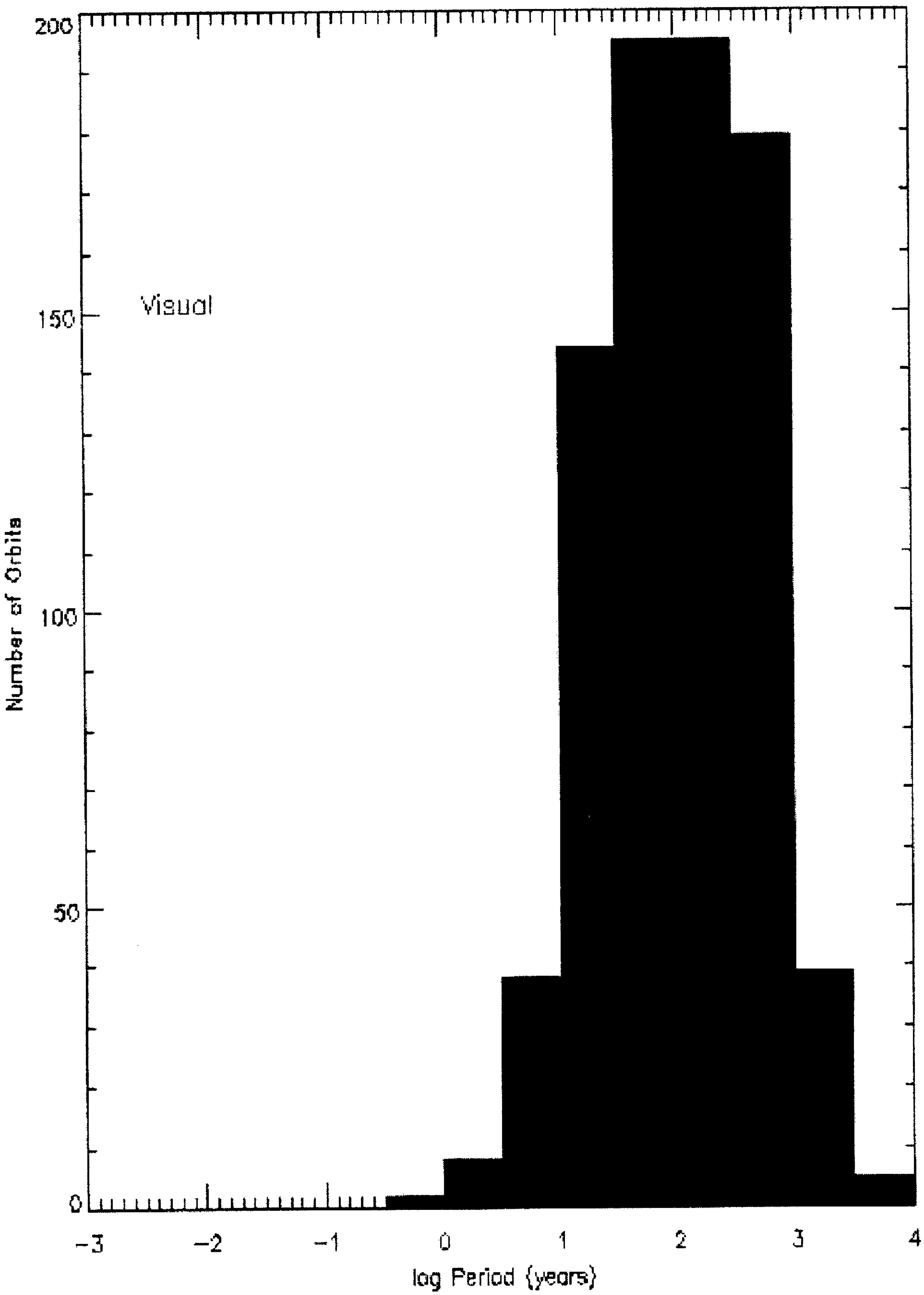
Improvements in spectroscopic techniques (coravel, other cross-correlation techniques) $\rightarrow$ measure smaller RVs $\rightarrow$ longer periods

Human lifespan limitations, however! Most improvement must come from "visual" side

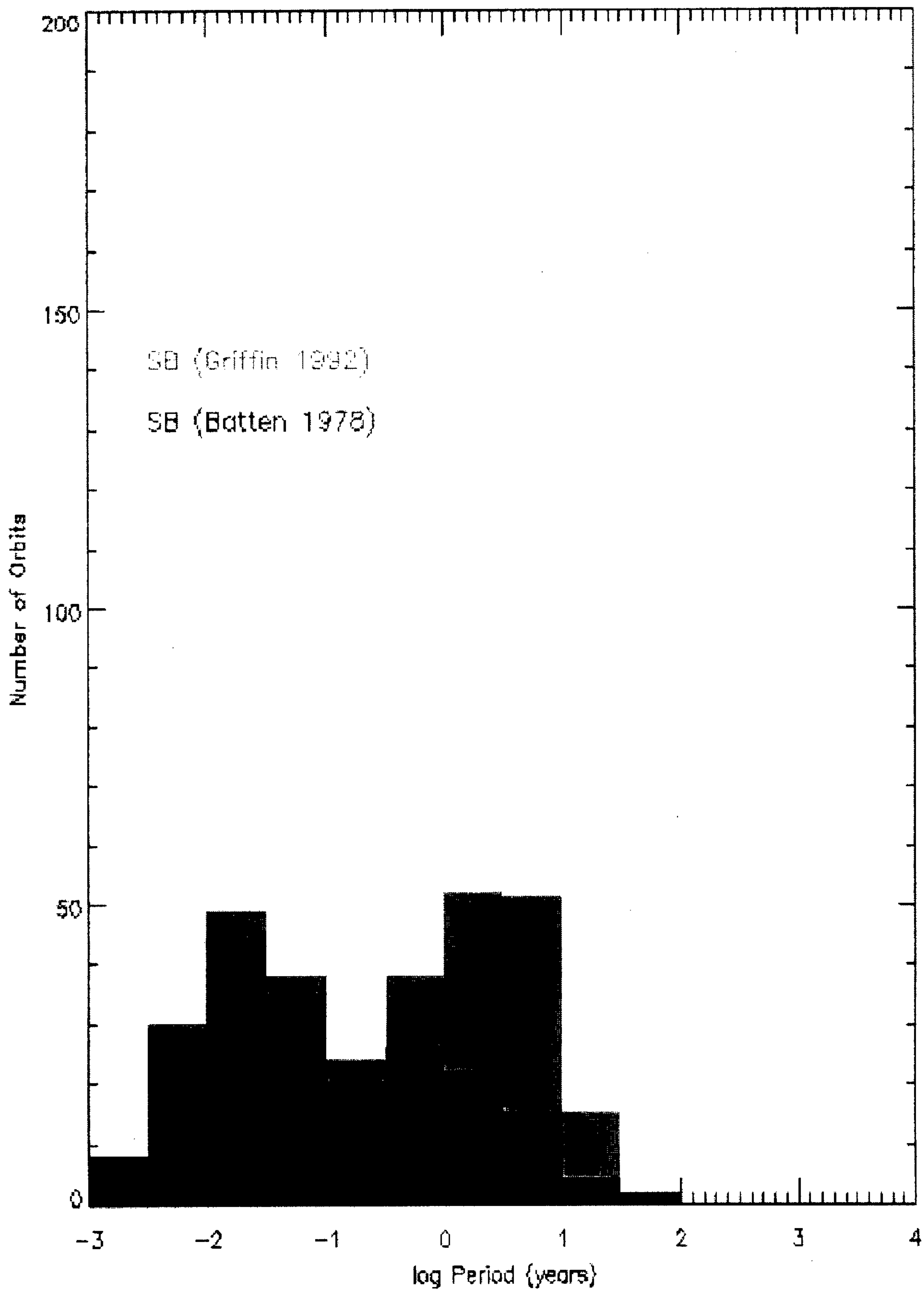
- Speckle: tens of mas $\rightarrow$ periods years to decades (25+ years' data)
- Mark III: periods weeks to years (bright stars, small numbers)
- NPOI: periods days (bright stars, just starting)

But why get masses?


SB (Batten 1978)
Number of Orbits
log Period (years)
200
150
100
50
0
-3
-2
-1
0
1
2
3
4



Visual
Number of Orbits
log Period (years)
200
150
100
50
0
-3
-2
-1
0
1
2
3
4



200
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SB (Griffin 1992)
SB (Batten 1978)
Number of Orbits
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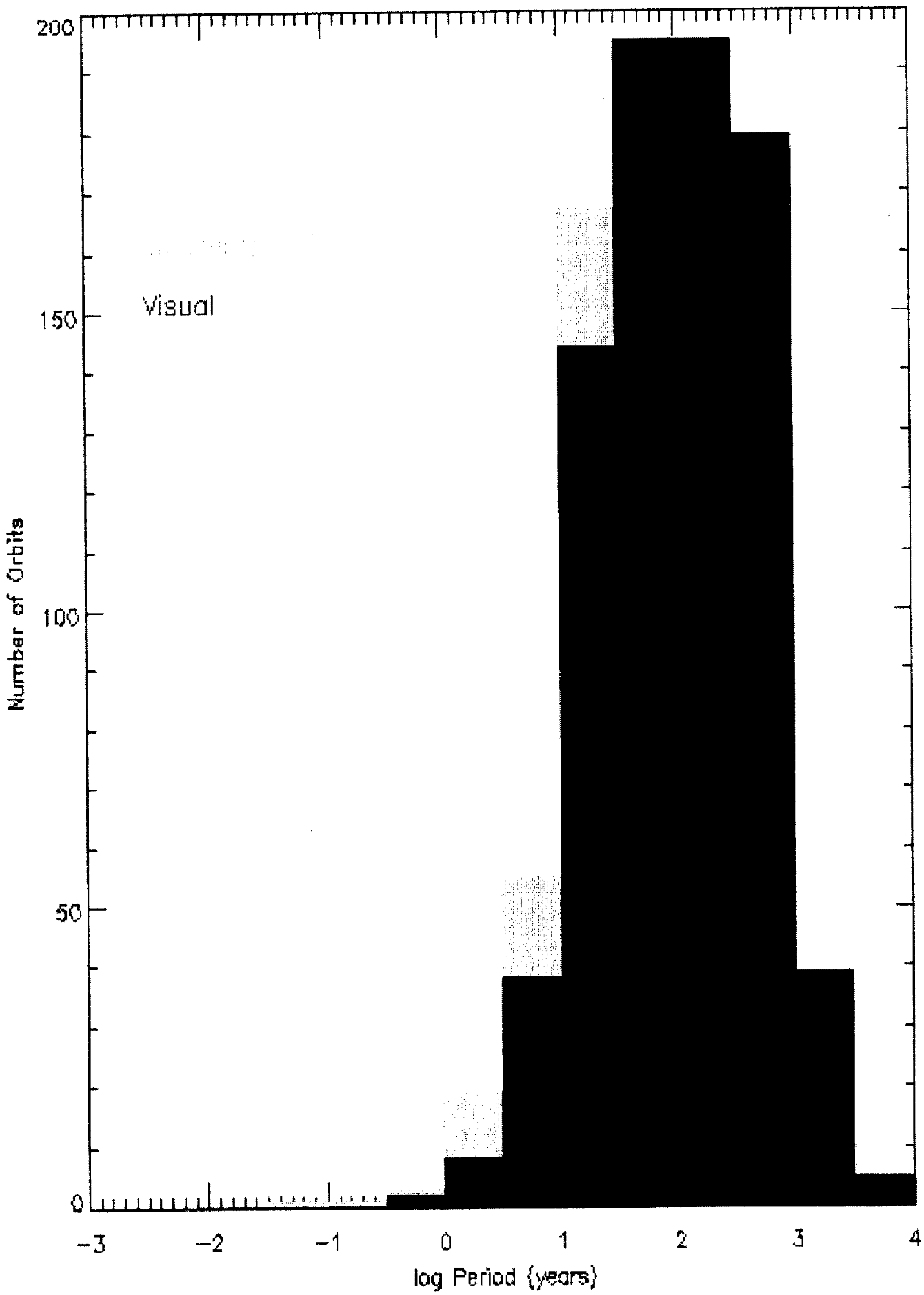
4
log Period (years)



Visual
Number of Orbits
200
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1
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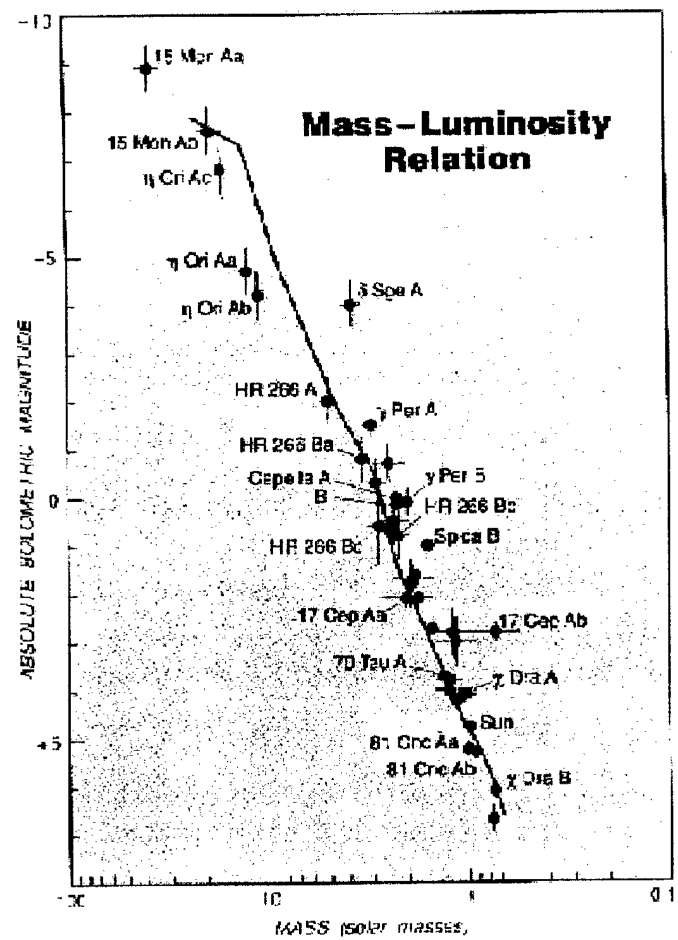
4
log Period (years)

Masses from Speckle Data



Reason 2: Binaries as Yardsticks

Spectroscopic + astrometric orbits $\rightarrow a'' + a \rightarrow$ distance ("orbital parallax")

Technique independent of spectral type, distance (sort of): works for stars for which trigonometric parallax doesn't

Reason 3: Binaries and Stellar Evolution

A few questions:

- What role does duplicity play in stellar evolution?
- Are ALL stars created in sets of 2 or more?
- Do all stars have a choice — either companions or planetary systems? Can they have both?
- Do stars of all spectral classifications show similar duplicity rate?
- How does duplicity change with time — i.e., once formed, how often are binaries disrupted?

Standard number: ~half of stars binaries

WDS: 450,000+ observations, ~80,000 stars, 200+ years. Sounds pretty good!

Surveys incomplete, however — true numbers not very well known!

- BSC: new "naked eye" stars found by speckle! Still 2/3 unchecked
- Hipparcos: 3,500 new binaries (many are observable visually)
- Surveys of stellar samples, but by no means thorough

Problem even worse — need complementary surveys for different separations.
Result: very few attempted.

One Tantalizing Survey Result

- PMS stars in young star-forming regions (ex.: Taurus–Aurigae, age 0.002 Gyr) have multiplicity rates ∼twice that for older (∼5 Gyr) solar–neighborhood counterparts. Hyades (0.7 Gyr) rate in between
- Leonard: binary-binary collisions in clusters and associations might eject stars, decrease their duplicity frequency compared to field stars
- Speckle of O stars: find lower frequency for cluster stars than field stars

Little known for $0.7 < \text{age} < 5$ Gyr — when do ejections occur?

Mason et al: surveyed ∼200 solar-type stars (speckle plus micrometry). Ages from chromospheric activity. Find duplicity fraction for more active stars (age ∼ 1 Gyr) about 18%, that for less–active stars (∼4 Gyr) 9%.

Need larger sample, data at smaller and larger separations.

Reason 4: Binaries in Other Guises

Effects of duplicity not always obvious!

Example: λ Boo variables:

- Weak metal lines (esp. Mg II)
- C, N, O, S nearly solar
- Most have moderate to high projected rotational velocities
- Types of stars?

Farraggiana & Bonifacio: find 1/4 – 1/3 show duplicity (most from speckle + Hipparcos)
Hypothesize most λ Boo stars actually normal binaries

How many types of variables thought due to duplicity? From Sterkin & Jaschek:

- **Eruptive variables:**
  1. RS CVn: close binaries with H and K Ca II in emission
  2. IN(YY): matter-accreting Orion variables
- **Eruptive supernovae and cataclysmic variables:**
  1. Novae (massive white dwarf/cool dwarf binaries): include fast, slow, very slow, recurrent types
  2. Nova–like systems (WD+WD, WD+MS, etc): include AM CVn, AM Her, DQ Her, UX UMa, VY Scl systems
  3. Type I supernovae
  4. Dwarf novae or U Gem variables: include SS Cyg, Z Cam, SU UMa, and Z And or symbiotic stars
- **Eclipsing variables:**
  1. EA: Algol types (N = 710 - 2000)
  2. W Ser systems: long-P Algol-like mass-transferring binaries
  3. EB: Beta Lyr types (N = 706 - 1500)
  4. EW: W UMa types (N = 88 - 1000)
  5. GS: have one or more giant components
  6. PN: one component is nucleus of PN
  7. WD: have white dwarf component
  8. WR: have Wolf-Rayet component
  9. AR: AR Lac type detached systems
  10. DM: detached MS systems
  11. DS: detached systems with subgiant
  12. DW: detached systems like W UMa system
  13. KE: contact systems of early spectral type
  14. KW: contact systems of late spectral type
  15. SD: semi-detached systems
- **X-ray sources:** 9 categories of bursters, novae, pulsars

What can interferometry contribute?

- Sizes, shapes of components, hot spots, dark spots, limb-darkening, etc. (other speakers)
- Masses + distances   true for other variables in binaries, as well
- Orbital inclination → trajectory during eclipses; aid study of extended atmospheres, accretion disks, etc.
- Orbital precession → study longer-term photometric, spectroscopic changes

Reason 5: Binaries as "Vermin"

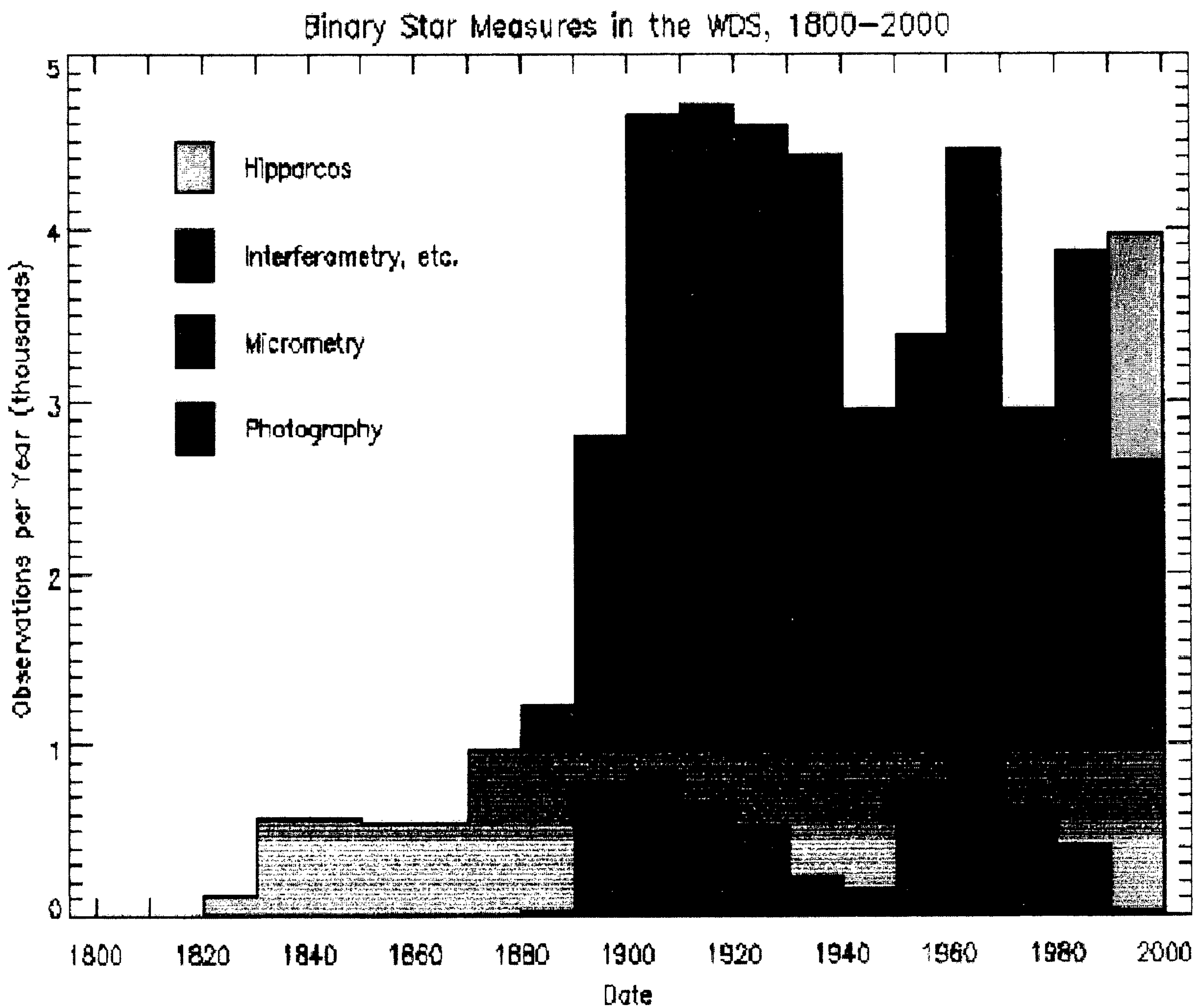
Some people despise binary stars!
(poor misguided fools)

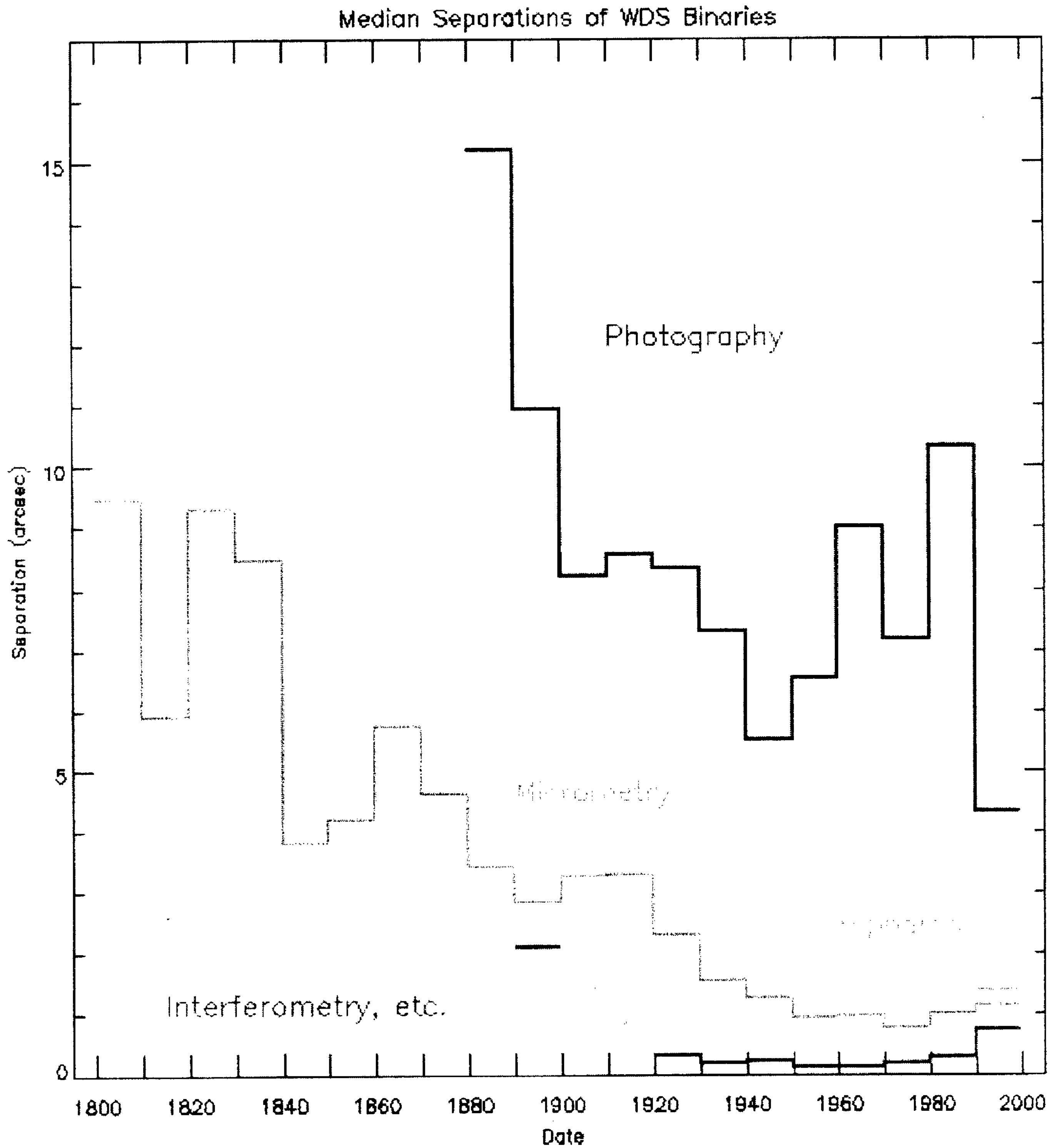
Reasons: need calibration point sources, guide stars for satellites, missiles, etc.

Example: SIM: needs 6,000 grid stars stable to 4 μas over 5 years

Advantage of interferometry over spectroscopy for surveys — one shot!

Current state of affairs — some good, some bad


Binary Star Measures in the WDS, 1800–2000
Hipparcos
Interferometry, etc.
Micrometry
Photography
Observations per Year (thousands)
0
1
2
3
4
5
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
Date


Median Separations of WDS Binaries
Photography
Interferometry, etc.
Separation (arcsec)
Date
0
5
10
15
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000